The Sidereal Messenger.

CONDUCTED BY WM. W. PAYNE,

Director of Carleton College Observatory.

APRIL, 1887.

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Thou Lord in the beginning hast laid the foundation of the earth, and the heavens are the works of thy hands.

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THE COMETS OF DE VICO, 1844 I, AND FINLAY, 1886 V.

H. C. WILSON, WASHINGTON, D. C.

For the Messenger.

The little faint telescopic comet discovered by De Vico, at Rome, August 22, 1844, would have excited little interest, but for the fact, first made known by Faye, that it was moving in an elliptic orbit of short period. The seven sets of elements of this comet, derived by different computers, agree very closely; the last and most accurate set, computed by Brünnow, was based upon all of the observations made during that apparition, and was corrected for the perturbations of all the planets. The resulting period was about 5.47 years. The comet ought therefore to have been observed, if not at any of the previous apparitions, at least at each second return since 1844. Such, however, has not been the case.

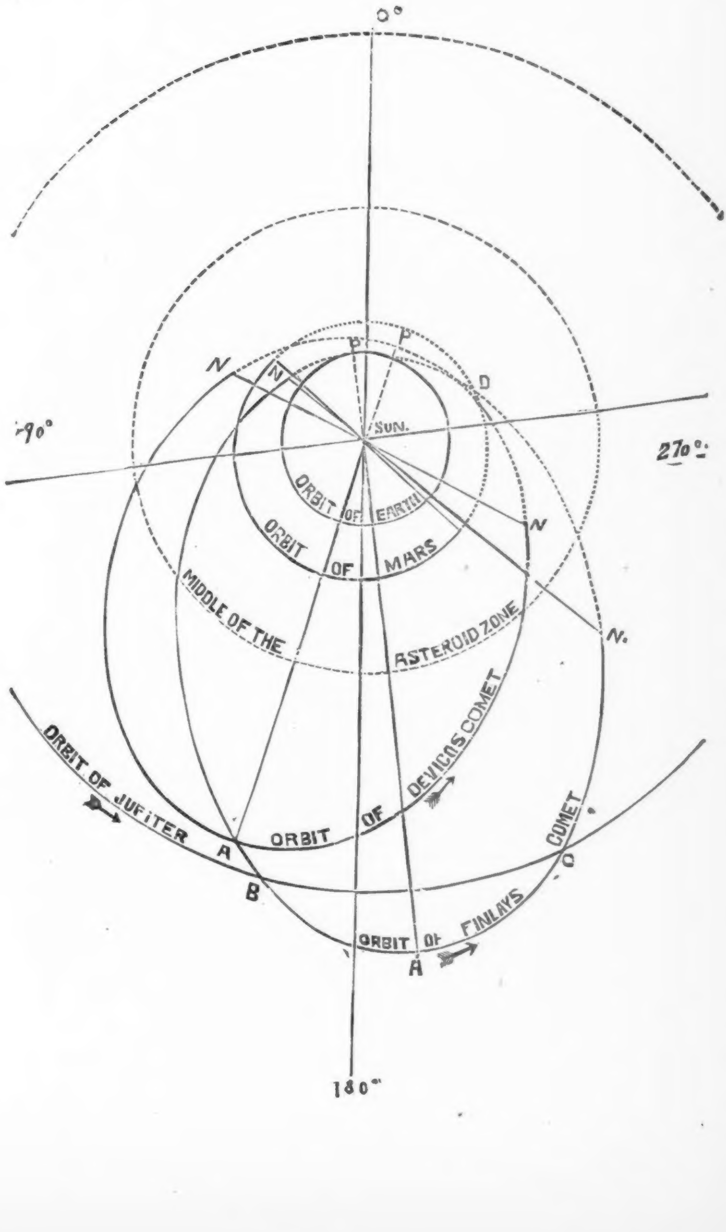
With regard to previous apparitions, Le Verrier in a memoir communicated to the *Astronomische Nachrichten*, Vol. 25, page 375, has discussed the possible identity of De Vico's comet with those of 1585, 1678 and 1770, whose elements bear some points of resemblance. The conclusion reached was strongly negative with regard to the comets of 1585 and 1770, but was quite favorable to the identity of the comets of 1678 and 1844. In this memoir Le Verrier pointed out the folly of inferring identity from mere similarity of the elements of two comets. He showed that in the case of this particular comet, the perturbations by the planet Jupiter under certain conditions might have produced a change of as much as 100° in the longitude of the nodes and 30° in the longitude of perihelion,

between the years 1770 and 1844. He showed also that this change must take place in certain directions, namely, that the longitude of perihelion must advance in the direction of Jupiter's motion, while the line of nodes must retrograde. A reference to the diagram may help to make this plain to the reader. Suppose the comet of De Vico and the planet Jupiter to pass the vicinity of the point *A* at the same time; the planet moves faster than the comet and its influence will draw the comet outward and around in the direction *AC*. The aphelion distance will thus be increased and the whole orbit will be swung around in the direction *AC*. Again, owing to the greater inclination of the comet's orbit, the point *A* is elevated above the plane of the planet's orbit, and the tendency will be to pull the comet down, causing its path to intersect the plane of the ecliptic before it reaches *N*. The line of nodes will therefore be revolved in a retrograde direction. A difference of 5° in the wrong direction in either of these elements necessitates, as a condition of identity, that the perturbations have produced a change of 355° instead of 5°; so that the elements of two comets may be apparently quite similar while they are really very different.

The closing words of Le Verrier's memoir will be of interest here:

"The comet of 1844 has probably come like the others from the far distant regions of space, and has been fixed among the planets by the powerful influence of the attraction of Jupiter. Its coming dates back, without any doubt, several centuries. Since that epoch it has passed quite frequently in the vicinity of the earth; but has been observed only once in the past centuries, 166 years before the apparition of 1844.

"This comet will for a very long time yet traverse the restricted orbit which we see it describe to-day. In a certain number of centuries, it will again reach to the orbit of Jupiter, in a direction opposite to that by which it came into the planetary system; and its course will certainly sometime be again changed. Perhaps even Jupiter will restore it to the space whence he has stolen it."



0°
90°
270°
180°
SUN.
ORBIT OF EARTH
ORBIT OF MARS
MIDDLE OF THE ASTEROID ZONE
ORBIT OF JUPITER
ORBIT OF DEVICOS COMET
ORBIT OF FINLAYS COMET
N
N
N
N.
D
P
A
B
A
C

Since the apparition of 1844 this comet has not been seen, if we except a single doubtful observation by Goldschmidt in 1855, although the conditions for observation, according to Brünnow's elements, have been quite favorable at several returns. The comet has become known as the Lost Comet of De Vico. It was natural, therefore, that when the computers found that the preliminary elements of Finlay's comet differed so little from those of the comet of 1844, they should conjecture that the two comets were the same. The later and more accurate computations do not tend to confirm this conjecture, but, as Professor Boss puts it, "render the question of identity with De Vico's comet rather problematical, to say the least."

Below I give, side by side, the elements of De Vico's comet by Brünnow, and the latest set of elements of the Finlay comet by Boss, from *Astronomical Journal* No. 150. The latter elements are based upon 35 observations, extending over the interval of time from September 29 to December 29, 1886. Both sets of elements are referred to the equinox of 1886.0.

	De Vico's Comet.	Finlay's Comet.
Time of perihelion passage	Sept. 2, 1844	Nov. 22, 1886
Longitude of perihelion	343° 06′ 20″	7° 33′ 02″
Longitude of node	64 24 30	52 26 14
Inclination	2 54 50	3 01 46
Perihelion distance	1.18640	0.99777
Eccentricity	0.61765	0.71855
Semi-major axis	3.10294	3.54519
Period	5.47 years.	6.675 years.

The most striking point of resemblance is in the inclination of the orbits to the plane of the ecliptic; this being almost exactly the same for both comets and but little greater than the inclination of the orbits of Mars and Jupiter.

The graphical method is the most satisfactory for comparing the other elements. The accompanying diagram shows the projection upon the plane of the ecliptic, of the orbits of the two comets and of the planets Earth, Mars and Jupiter. In the case of each of these bodies the inclination is so small that, on the scale used, the dimensions of the real orbits do not differ appreciably from their projections. Those parts of

the curves which lie below the plane of the ecliptic are represented by dotted lines.

A glance at the diagram shows that, to satisfy the hypothesis of identity, the comet must have been subject to violent perturbations at some time between 1844 and 1886. The differences in direction of the major axes, *AP* and *A'P'*, and the lines of nodes, *NN* and *N'N'*, accord with Le Verrier's criterion in regard to the perturbations by Jupiter, namely, that the perihelion must advance while the nodes must retrograde. The intersection of the two comet orbits at *A*, the point where De Vico's comet approaches nearest to Jupiter's path, would also lead us to suspect that Jupiter might have had something to do with the disturbance ; but we encounter serious difficulty in bringing the three bodies together in that vicinity. The heliocentric longitude of the point *A* is approximately 168°, and if we work forward from 1844.67 with the period 5.47 years, and backward from 1886.90 with the period 6.68 years, we find the following dates when the three bodies were in that longitude :

De Vico's Comet.	Finlay's Comet.	Jupiter.
1847.40	......	......
52.87	1848.72	1850.26
58.34	55.40	......
63.81	62.08	62.12
69.28	68.76	......
74.75	75.44	73.98
80.22	1882.12	......
1885.69	......	1885.84

It appears that the Finlay comet and Jupiter passed the point *A* together about 1862.1, but that the De Vico comet was then 1.8 years behind. In order to bring the three together at that epoch, the period of De Vico's comet must be either diminished to 5.0 years or increased to 6.9 years, both of which suppositions are improbable.

There is an interesting conjunction of intersections of the paths of the comets and Mars at *D*, in longitude 285°—300°. The distance between the planes of the orbits is there very

small. Examining, in the same manner as before, the dates at which the comets and the planet were in longitude 288°, we find the following:

De Vico's Comet.	Finlay's Comet.	Mars.
1849.96	1853.26	1852.96
55.43	......	54.84
60.90	59.94	60.49
66.37	66.62	66.14
71.84	......	71.79
......	73.30	73.67
77.31	......	77.44
......	79.98	79.32
1882.78	......	83.08
......	1886.66	1886.84

The nearest approach to coincidence of dates here is in 1866, but the divergence is still so great that it can hardly be accounted for by errors in the assumed periodic times of the comets.

From this superficial examination it would seem that the probability of identity of these two comets is extremely small. Before undertaking a rigorous investigation of the question, it will be necessary to know the mean motion of Finlay's comet with exactness. This we cannot hope to know with certainty until a second apparition shall have been observed. The next perihelion passage will occur in the summer of 1893, and, unless the period 6.68 years is considerably in error, will be only a little less favorable for observation than the present one. As no remarkable perturbations are likely to take place meanwhile, it is quite probable that the comet may then be reobserved. Until then it will be hardly worth while to attempt to compute the past perturbations of Finlay's comet, in the vain hope of identifying it with that of De Vico. It will be advisable, however, to obtain the best possible elements from the observations at this apparition and to compute the perturbations by all of the planets during the next seven years, in order to predict the course of the comet as closely as possible in 1893.

Washington, February 12, 1887.

THE METEORITES, THE METEORS AND THE SHOOTING STARS.

PROFESSOR H. A. NEWTON.

(Continued from page 105.)

What that structure is, and to some extent what conditions must have existed at the time and place of its first formation and during its subsequent transformations, mineralogists rather than astronomers must tell us. For a long time it was accepted without hesitation that these bodies required great heat for their first consolidation. Their resemblance to the earth's volcanic rocks was insisted on by mineralogists. Professor J. Lawrence Smith in 1855 asserted without reserve that "they have all been subject to a more or less prolonged igneous action corresponding to that of terrestrial volcanoes." Director Haidinger, in 1861, said "With our present knowledge of natural laws the characteristically crystalline formations could not possible have come into existence except under the action of high temperature combined with powerful pressure." The likeness of these stones to the deeper igneous rocks of the earth as shown by the experiments of M. Daubrée strengthened this conviction.

Mr. Sorby in 1877 said, "It appears to me that the conditions under which meteorites were formed must have been such that the temperature was high enough to fuse stony masses into glass; the particles could exist independently one of the other in an incandescent atmosphere, subject to violent mechanical disturbances; that the force of gravitation was great enough to collect these fine particles together into solid masses, and that these were in such a situation that they could be metamorphosed, further broken up into fragments, and again collected together."

Now if meteorites could come into being only in a heated place, then the body in which they were formed ought, it would seem, to have been a large one. But the comets, on the contrary, appear to have become aggregated in small masses.

The idea that heat was essential to the production of these

minerals was at first a natural one. All other known rock formations, are the result of processes that involved water or fire or metamorphism. All agree that the meteorites could not have been formed in the presence of water or free oxygen. What conclusion was more reasonable than that heat was present in the form of volcanic or of metamorphic action?

The more recent investigations of the meteorites and kindred stones, especially the discussions of the Greenland native irons and the rocks in which they are imbedded, are leading mineralogists, if I do not mistake, to modify their views. Great heat at the first consolidation of the meteoric matter is not considered so essential. In a late paper M. Daubrée says "It is extremely remarkable that in spite of their great tendency to a sharply defined (*nette*) crystallization, the silicate combinations which make up the meteorites are there only in the condition of very small crystals all jumbled together as if they had not passed through fusion. If we may look for something analogous about us, we should say that instead of calling to mind the long needles of ice which liquid water forms as it freezes, the fine grained texture of meteorites resembles rather that of hoar frost and that of snow, which is due, as is known to the immediate passage of the atmospheric vapor of water into the solid state."

So Dr. Reusch from the examination of the Scandinavian meteorites concludes that "there is no need to assume volcanic and other processes taking place upon a large heavenly body formerly existing but which has since gone to pieces."

The meteorites resemble the lavas and slags on the earth. These lavas and slags are formed in the absence of water, and with a limited supply of oxygen, and heat is present in the process. But is heat necessary for the making of the meteorites? Some crystallizations do take place in the cold; some are direct changes from gaseous to solid forms. We cannot in the labratory reproduce all the conditions of crystallization in the cold of space. We cannot easily determine whether the mere absence of oxygen will not account fully for the slag-like character of the meteorite minerals.

Wherever crystallization can take place at all, if there are present silicon and magnesium and iron and nickel with a limited supply of oxygen, there silicates ought to be expected in abundance, and the iron and nickel in their metallic form. Except for the heat the process should be analogous to that of the reduction of iron in the Bessemer cupola where the limited supply of oxygen combines with the carbon and leaves the iron free. The smallness of the comets should not then be an objection to considering the meteoric stones and irons as pieces of comets. There is no necessity of assuming that they were parts of a large mass in order to provide an intensely heated birth-place.

But although great heat was not needed at the first formation there are many facts about these stones which imply that violent forces have in some way acted during the meteorites' history. The brecciated appearance of many specimens, the fact that the fragments in a breccia are themselves a finer breccia, the fractures, the infiltrations and apparent faultings seen in microscopic sections, and by the naked eye,—these all imply the action of force.

M. Daubrée supposes that the union of oxygen and silicon furnishes sufficient heat for making these minerals. If this be possible those transformations may have taken place in their first home. Dr. Reusch argues that the repeated heating and cooling of the comet as it comes down to the sun and goes back again into the cold is enough to account for all the peculiarities of structure of the meteorites. These two modes of action do not, however, exclude each other.

Suppose then, a mass containing silicon, magnesium, iron, nickel, a limited supply of oxygen and small quantities of other elements, all in their primordial or nebulous state (whatever that may be) segregated somewhere in the cold of space. As the materials consolidate or crystallize, the oxygen is appropriated by the silicon and magnesium, and the iron and nickel are deposited in metallic form. Possibly the heat developed may, before it is radiated into space, modify and transform the substance. The final result is a rocky mass (or possibly sev-

eral adjacent masses) which sooner or later is no doubt cooled down throughout to the temperature of space.

This mass in its travels comes near to the sun. Powerful action is there exerted upon it. It is heated. How intense is that heat upon a cold rock unprotected apparently by its thin atmosphere, it is not possible to say. We know that the sun's action is strong enough to develop and drive off into space, that immense train, the comet's tail, that sometimes spans our heavens. It is broken in pieces. We have seen the portions go away from the sun, to come back probably as separate comets. Solid fragments are scattered from it to travel in their own independent orbits.

What is the condition of the burnt and crackled surface of a cometic mass or fragment as it goes out from near the sun again into the cold? What changes and re-crystallizations may not that surface undergo before it comes back to pass anew through the fiery ordeal? We have here forces that we know are acting. They are intense, and act under varied conditions. The stones subject to those forces can have a history full of all the scenes and actions required for the growth of such strange bodies as have come down to us. Some of our meteors, those of the star-showers, have certainly had that history. What good reason is there for saying that all of them may not have had the like birthplace and life?

Before I close let me recite one lesson that has been taught us by the recent star-showers. The pieces which come into our air, in any recurring star-shower, belong to a group whose shape is only partly known. It is thin, for we traverse it in a short time. It is not a uniform ring, for it is not annual, except possibly the August sprinkle. How the sun's unequal attraction for the parts of a group acts as a dispersive force to draw it out into a stream, those most beautiful and most fruitful discussions of Signor Schiaparelli have shown. The groups that we meet are certainly in the shape of thin streams.

It has been assumed that the cometic fragments go continuously away from the parent mass so as to form in due time a ringlike stream of varying density, but stretched along the en-

tire elliptic orbit of the comet. The epochs of the Leonid star-showers in November, which have been coming at intervals of thirty-three years since the year 902, have led us to believe that this departure of the fragments from Tempel's comet (1866, I) and the formation of the ring was a very slow process. The meteors which we met near 1866, were, therefore thought to have left the comet many thousand years ago. The extension of the group was presumed to go on in the future, until, perhaps tens of thousands of years hence, the earth shall meet the stream every year.

Whatever may be the case with Tempel's comet and its meteors, this slow development is not found to be true, for the fragments of Biela's comet. It is quite certain that the meteors of the splendid displays of 1872 and 1885 left the immediate vicinity of that comet later than 1840, although at the time of those showers they had become separated two hundred millions of miles from the computed place of the comet. The process then has been an exceedingly rapid one, requiring, if continued at the same rate, only a small part of a millennium for the completion of an entire ring, if a ring is to be the finished form of the group.

It may be thought reasonable in view of this fact about Biela's comet established by the star-showers of 1872 and 1885 to revise our conception of the process of disintegration of Tempel's comet also. The more brilliant of the star-showers from this comet have always occurred very near the end of the thirty-three year period. Instead of there being a slow process which its ultimately to produce a ring along the orbit of the comet, it certainly seems more reasonable to suppose that the compact lines of meteors which we met in 1866, 1867 and 1868 left the comet at a recent date. A thousand years ago this shower occurred in the middle of October. By the precession of the equinoxes and the action of the planets, the shower has moved to the middle of November. One-half of this motion is due to to the precession of the equinoxes, the other half to the perturbing action of the planets. Did the planets act upon the comet before the meteorids left it, or upon the meteoroid

stream? Until one has rednced the forces to numerical values, he may not give to this question a positive answer. But I strongly suspect that computations of the forces will show that the perturbations of Jupiter and Saturn upon that group of meteoroids hundreds of millions of miles in length, perturbations strong enough to change the node of the orbit fifteen degrees along the ecliptic, would not leave the group such a compact train as we found it in 1866. If this result is at all possible, it is because the total action is scattered over so many centuries. But it seems more probable that the perturbation was of the comet itself, that the fragments are parting more rapidly from the comet than we have assumed, and that long before the complete ring is formed the groups become so scattered that we do not recognize them, or else are turned away so as not to cross the earth's orbit.

Comets by their strange behavior and wondrous trains have given to timid and superstitious men more apprehensions than have any other heavenly bodies. They have been the occasion of an immense amount of vague and wild and worthless speculation by men who knew a very little science. They have furnished a hundred as yet unanswered problems which have puzzled the wisest. A world without water, with a strange and variable envelope which takes the place of an atmosphere, a world that travels repeatedly out into the cold and back to the sun and slowly goes to pieces in the repeated process, has conditions so strange to our experience and so impossible to reproduce by experiment that our physics cannot as yet explain it. Yet we may confidently look forward to the answer of many of these problems in the future. Of those strange bodies, the comets, we shall have far greater means of study than of any other bodies in the heavens. The comets alone give us specimens to handle and analyze. Comets may be studied, like the planets, by the use of the telescope, the polariscope and the spectroscope. The utmost refinements of physical astronomy may be applied to both. But the cometary worlds will be also compelled, through these meteorite fragments with their included gases and peculiar minerals, to give

up some additional secrets of their own life and of the physics of space to the blowpipe, the microscope, the test-tube and the crucible.

KEPLER'S CORRESPONDENCE IN 1599.*

(Continued from page 112.)

4. In the year 1595, April 23, I myself saw, as you also did, that the eclipse of the moon occurred later than it was placed by the Prussian calculation. This again confirms my view. For in the month of April this seems to me to happen of necessity.

5. You see the eclipse of the sun for the year 1598 is placed by Tycho himself 10¾ digits north and later (for the one follows the other, as I have shown in my appendix) by myself also it is received in this very way, and is given a fundamental position.

6. In the year 1590 the eclipse of the sun was seen at Tübingen by Mästlin in my presence, to appear in like manner earlier and smaller. This is just in accordance with my principles, for the sun was beyond apogee in Leo.

Finally you recount in order the eclipses before CHRIST, which are obtained by each calculation with a difference of almost three hours. This also confirms my view. For since my calculation is accommodated to daily observations, the observations approximate the calculation of Alphonso, therefore I also approximate the calculation of Alphonso, and the more constantly I do this, with greater accuracy. But even before the time of CHRIST I do this, which I thus prove. My correction and difference of the lunations introduced depend upon the eccentricity of the sun. That was once greater, wherefore my difference also was necessarily greater: so also the Prussian tables evidently differ more at that time from the tables of Alphonso. I do not say this with accurate knowledge but conjecturing. For Reinhold in his Prussian tables shows how much must be attributed to the tables of Alphonso in making investigation of antiquity, who commends Coperni-

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* Translated from the Latin by Professor Louisa H. Richardson, Carleton College.

cus for this especially, because he teaches how to compute ancient eclipses, when no one before could do it. But yet the tables of Alphonso seem to have been especially accurate in the case of the moon. And they, perchance, looked chiefly to the eclipses of spring, as Copernicus to those of summer and winter. Hence the former èrr in the eclipses of summer and winter, Copernicus in those of spring and autumn. Copernicus was devoted to matters of greater importance, determining the eccentricity of the sun, measuring the length of the year. To obtain these, it was impossible to teach otherwise concerning the eclipses, unless he should introduce at the same time a new and yearly irregularity in the moon ; and I do this, although he was not inclined to. Perhaps it may also be important to state, if the Ptolemaic eccentricity of the sun be retained, the eclipses of Copernicus would agree with the observations to-day. For I attribute this yearly irregularity to the moon, that is the same, as if the eccentricity of the sun increased, while the moon continued in uniform motion.

Beside testing my opinion, you also set forth that of another, concerning the introduction of a new motion of the earth. And I indeed have already said how it could be by a simple increase of the eccentricity which is not a new motion.

And Tycho also makes another suggestion in his letters written to me: for he says, the orbit of the sun (according to Copernicus the earth's orbit) is sometimes increased, sometimes diminished: that this may be physically possible, he eliminates the real or solid orbits from the heavens, and I do not object to it, though for other reasons. This then we shall see in his works if God permit us. On the celestial globe, which you perchance have, he says that he observes a certain and very slow declination of the Zodiac, so that the same constellations do not remain fixed in the Zodiac. This in like manner Copernicus refers to the earth. And thus let a suggestion be enough for us regarding a new motion of the earth. But in my appendix you have a two-fold reason why the moon rather should be the cause of these errors in eclipses. For, in the first place, the same irregularity of the moon is seen also when

it is compared with the fixed stars or planets, not so much when it is compared with the sun and its shadow. Then, the whole theory concerning the equinoxes and the length of the year would be thrown into great confusion, if the eccentricity were changed. I am unequal to settling this confusion. Tycho has the power, let him then see to it. For he maintains that this, which Copernicus gives, is not the reason for the equinoxes. To depart now from the eclipses, since this subject is ended, it would please me to discover something concerning the declination of the ecliptic, but philosophically from my cosmography which I am thinking upon. Certainly, the declination is not to-day at its minimum, but will decrease through many centuries (if time continue) even to a mean of 22° 30′, and perhaps beyond. For I am convinced that the mean was 22° 30′ in the beginning of the world; then it increased through four thousand years to 24°. So that in the first or second century before Christ the mean was found by the masters to be 23° 52′, which Copernicus makes the maximum. Further, in a single revolution the motion is quite frequently unequal. Then by Ptolemy again it was observed 23° 52′. (Notice that I do not here reply to the Obelisk of Pliny.) Then it decreased more quickly, to-day it decreases slowly, and is 23° 28′, but this decrease will continue (to increase again) even to the 2400th year from this returning to the primeval mean, 22° 30.′ Copernicus used to say, the earth was moved from the center, the greater the eccentric was made, the more also it was inclined to the Zodiac at the poles. But from what dream, you say, do you derive this 22° 30′? From the cosmography, I answer. Consider what it would have been, if the equator had not deviated from the ecliptic; what also, if it had deviated a whole quadrant, for these are extremes. Afterwards consider the varying phenomena of the declination of orbits 45°, the mean between the extremes, then of the declination 67° 30′, the mean between 45° and 90°, also of the declination 22° 30′, the mean between 0° and 45°. Examine these yourself, for the matter is easy to think upon, troublesome and long to write. You will find that the equali-

ty of any declination corresponds to the laws of the universe and the too great inequality is neither 90° nor 67° 30′ nor 45°. There remains then only the 22° 30′, and since this number approximates the number 23° 28′ of to-day's declination and the declination is still decreasing, for this reason have I fallen upon this suspicion of mine. For in the whole bodily structure, God has given laws of the body, number and proportions, the best chosen and well regulated laws. Wherefore the parts of the orbits are rational, as is 22° 30′, which is the sixth part of any meridian, while 23° 28′, 23° 52′ or the mean 23° 40′ are not rational parts. This also favors my suggestion, that all may be varied by motion, and return to themselves that there may be as great variety as possible. Wherefore I agree with Tycho also concerning the obliquity of the Zodiac. In this way the latitude of the zones will be made equal in creation, on a meridian which is divided into eight parts of which each holds one from the frigid, two from the temperate and torrid, in opposite places. Hence God accomplished this, that the mean should lie between the extremes, the temperate between the frigid and torrid, and this law has been of great value in the arrangement of the world. For this law is also among the planets, if not all, certainly the greater ones, Saturn, Jupiter, Mars, Venus, Mercury. These five: for we may except the earth, since even God has called it an exception adorning it alone with the orb of the moon. Accordingly you see Saturn pale, Jupiter yellow, Mars red, Venus golden, Mercury silvery. Saturn and Mercury, the extremes, correspond in color, so Jupiter and Venus, lying between, while Mars has no corresponding planet. Thus God seems to have given the planets to the zones, or the zones to the planets. For Saturn is frigid, Jupiter, temperate, Mars, torrid; the color is an indication, and the astrologers bear witness; unless the same nature and condition does not extend far within to Saturn and Mercury, Jupiter and Venus, as to the frigid and temperate zones each. For Venus and Mercury are nearer the sun, separated from the earth by the higher ones. Wherefore they are more brilliant also than Jupiter and Saturn.

Let us cease therefore to investigate celestial and incorporeal things, more than God has revealed to us. These things are within the grasp of human understanding. God wishes us to know these, since he has fashioned us in his own image, that we may come into participation of the same reasoning with himself. For what is in the mind of man beyond numbers and quantities? These things alone do we rightly understand and if it can be said with reverence, with the same kind of thought as God, as much indeed as we do comprehend of these things in our mortality. Foolishly do they fear that we shall make man a God; the counsels of God are inscrutable, not his corporeal works. For what are the works of God, if they are compared with his counsels? The counsels of God are God himself, but the works are his creatures, and it is not a great thing for God to create man capable of understanding his works. But let us return to your letter. I think the opinion of Pliny and of the ancients concerning the equinoxes—when on 8 of Aries—together with Scaliger arose from this, because the solstices continued apparently sixteen days, (athough from this I do not affirm anything disparaging the Obelisk of Pliny, that I may not make him too unskilled in astronomy. For it is one thing to remain fixed and another thing to revolve; the former is rest, the latter motion. Wherefore as long as the day did not increase perceptibly, the sun was thought to stand still, and the solstice was said to continue. But as soon as the increase of the day was observed, then the sun was said to turn. Hence, revolution on the eighth day. Afterwards even the days of the equinoxes were computed from the revolutions.

The pearls of philosophy, gathered from Arabic nonsense, belong to that matter which Aristotle treats of in his books on generation and destruction and on meteors. Some I have shown in the preface of this year's prognosticon, which you have. They are simply wonderful, and because they rightly try one's patience, the zeal of the Academic philosophers grows cold in things so noble. I think that on account of the countless trifles, which are rightly to be despised by the wise, it

happens that the pearl also is scorned. Just as a cock will have little faith in me advising him to hide something good, for he will see the dung-hill and will dig. I will set forth some points through questions.

1. How are all moistures connected with the light of the moon? 2. Why are the ocean tides caused by the motion of the moon? 3. How can position effect anything, and, indeed, not all position, but only the *rational*. For every appearance is a rational position, a harmonious part of the four right angles, caused by the rays of the stars coming together on the earth. And since there are eight harmonies, unison, minor third, major third, fourth, fifth, minor sixth, major sixth, octave, there will also be eight radiations, as is in my little book, cosmography: conjunction, sextilis, quintilis, quadratus, trigon, sesquiquadratus, biquintiiis, opposition. (Symbols omitted.) And why should they not have an influence, since the same plan embraces these as the ancient and accustomed. This whole question is worthy the genius of natural philosophers. Behold to-day, when two planets are distant 89°, nothing new happens in the meteors. To-morrow, when they are full 90° distant, that is, a quadrant, suddenly a storm arises. How little addition is made to the light of each within one day, and how on the day after to-morrow can that be again quickly diminished? Therefore it is not the effect of a star, but of stars; not of light but of the number 90°, that is the angle counted by the number 90°, a rational and harmonious part of the whole circle. The earth itself, then, by its own position aids this effect, since if it were situated any where else, it would be in another angle. But what can position accomplish? What can reason do, unless that which acts, comprehends reason? Or shall we give life to the light? I preferred to give life to the earth, which is suited for understanding these appearances, as you will comprehend more clearly n my preface.

(To be continued.)

THE SUN-SPOTS AS VORTEX RINGS.

FRANK H. BIGELOW.*

For the Messenger.

In order to emphasize the need of a new theory on the origin of sun-spots, it will be advisable to enumerate the most important suggestions heretofore made. The most superficial observations indicated the following general appearances to be explained, namely, a circular spot having a dark center, a radiated hotter ring of remarkable uniform structure in width, brighter than the center and duskier than the average face of the sun, the whole region being hollow and depressed, and the scene of great activity as indicated by flames of different kinds. The early observers proposed "planets circulating very near the surface;" Galileo, "clouds floating in the solar atmosphere;" Derham and Capocci, "solar volcanoes;" Lalande, "solar mountain tops, like islands in an ocean of fire;" Herschel, "holes temporarily opening in the two enveloping clouds, the photosphere and the penumbral cloud, showing a dark, cool, solid sun;" Sir John Herschel, "great whirling storms boring down through the photosphere;" Secchi, "openings in the photosphere caused by gases bursting out in eruptions;" Zöllner, "the solar surface a liquid in which float slag-like cooler masses;" Secchi (modified), "dense clouds of eruption products settling down near but not at the place of eruption, as the resultant of component velocities;" Faye, "whirlpools caused by polar-equatorial currents, forming tangential vortices;" Young, "sinking spaces in the photosphere, due to diminution of upward pressure from below;" Norton, "diminished gaseous pressure and electric tension;" Siemens, "superficial convection currents from stellar regions circulating over poles toward the equator of the sun." A sufficient summary of objections can be found in Professor Young's book on the Sun, pp. 166–178. The statements which accompany these theories in many cases contain exact descriptions of conditions

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which must exist on the Sun, and the utmost value will always be attached to them.

That the comparison of vortex rings and sun-spot phenomena may be more readily apprehended, it will be expedient to recapitulate the mathematical relations known to exist, referring to the works of the illustrious authors (Helmholtz, Sir William Thomson, Tait, Craig, Lamb,) for details of the subject. Pure mathematics deals with the ideal, frictionless vortex ring as applied so beautifully in Thomson's Theory of Atoms, and hence it is to be expected that a modified though natural type shall be seen in the sun, where the elements of pressure and friction must be introduced. A perfect fluid is homogeneous, incompressible and devoid of all viscosity. In such a fluid, motion about an instantaneous axis is called irrotational, as distinguished from rotation about a fixed axis. When such a motion is impressed upon any portion of a perfect fluid, the mass in motion will remain the same; the volume is invariable, though the form may change; the density is uniform in all parts; the volume of the fluid contained in any closed surface is proportional to the volume contained within that surface; the stress between contiguous portions is always normal. The Theorem of Helmholtz is, that the points lying on a vortex line continue to lie on the same line during the whole motion; or the same row of particles forming a vortex line swims along with the fluid, in such direction as at every point to coincide with the axis of rotation. A vortex tube is formed of an integrated series of vortex filaments, which in turn are vortex lines integrated from consecutive points. The quantity which flows through any section of the same tube in the unit of time must be invariable, and at any section the product of the area of the section into the mean velocity of rotation is constant. The velocity of circulation at any section varies inversely as the area of that section, and that of any segment directly as the length of the segment. From these laws are deduced the properties that vortex rings are either closed and return into themselves, or have two sections in one free surface; are indestructible and indivisible;

tend to separate themselves from one another and from surrounding portions of the same fluid.

Such vortex motion is an ideal mathematical conception and cannot be reproduced by experiment, but the motion as modified in a viscous fluid can be reproduced to illustrate these laws, as has been shown in Tait's Lectures on Physics. Popular examples are seen in smoke rings of a locomotive. The types of modification may serve as a topic of research in physical laboratories promising a rich reward for labor and expense of apparatus. When such a ring is thrown into a medium of condensation and pressure, the natural expansion produced by the absorption of heat caused by the friction upon the revolving surfaces, instead of going on as a simple enlargement of the ring to the state of dissolution, will cause an intermediate process of folding the surface so as to follow the lines of the rotating sections, till the uniform ring disintegrates into a series of secondary rings at right angles with the core of the original ring. This generation of heat is accompanied by a retardation of the velocity of rotation, so that eventually the secondary rings, losing their momentum, will have only such a low velocity as fails to preserve the typical form, and they therefore float away like heterogeneous masses without character into the surrounding fluid wherein they were formed.

So far as we know, the origin of rings possible to be formed by experiments is accompanied by a blast of fluid having considerable velocity through a channel of relatively hard walls, upon whose sides the friction retards the outer layers of the column, while the inner being unimpeded give rise to a ring, all of whose particles rotate radially from center forward in the direction of translation, returning on the outside and thus preserving an integrity. When the ring is thus ejected it travels on indefinitely till the friction disintegrates it. Should it enter a denser medium the same destruction could only be hastened but not changed in type. The larger the volume of the original ring, the greater the power it has in any given medium to resist the influences of friction, since the volume increases more rapidly than the containing surface.

Let us apply this theory to the phenomena on the sun. On pages 175 and 286, Professor Young, quoting Maxwell and others, states what is doubtless the truth, that "at a high temperature the viscosity of gases is vastly increased, so that quite probably the matter of the solar nucleus resembles pitch or tar or putty in its consistency." The low density of the sun indicates either a large sphere, gaseous throughout, or a solidifying nucleus at the center, surrounded with a space occupied by convection currents only, and this surmounted by a shell of condensation at the extremity of the cooling radius, which forms the visible surface of the sun. The viscous surface of the nucleus is the agent of contraction upon the enclosed gases in relative stages of condensation, producing an accumulation of pressure by its volume diminishing in consequence of the continuous radiation of heat. The relief from this pressure is the frequent discharge of the confined gases, through the sticky, semi-solid outer wall, where they are puffed out under all the circumstances tending to produce a vortex ring. The liberated ring springs upward in a parabolic path under the components of velocity caused by the force of ejection, and the rotation of the nucleus on its axis, being practically unimpeded except by a retardation of its acceleration, till it strikes the envelope called the photosphere. The resolved tangential velocity at this point will give as the area of impact, that part of the ring which is towards the east, as seen from the center of the sun, while at the same time the normal component continues to act upwards. Under the influence of these two forces the ring begins to bore its way upward and eastward until it finally emerges as a perfect spot, or in case the normal component fails in this work, as a veiled spot. The hollow ring has the capacity of sending ahead of it a short, gusty current produced by the friction of its inside surface upon the medium in which it travels, and this will cause an antecedent rending of the superincumbent cloud in the irregular forms so well known, together with the elevated or bubble shape of the photosphere which heralds a spot at any locality.

It is clear that the retardation of the ring tends to enlarge the sectional area of circulation, in addition to the expansion of the gases freed from the pressure at the nucleus, so that by the time it appears at the surface of the photosphere it has become enormously larger than when it set out on its upward journey. It may be suggested also that this enlargement is so governed as to adapt itself in a degree to the general thickness of the photosphere at the place of apparition, as a consequence of which the thickness of the ring and of the photosphere is nearly the same ; or at least they may be supposed to differ by some such constant quantity as is detected in the usual depression of the spot below the surface, a result which would naturally be caused by the friction sucking down the medium in its immediate neighborhood.

If this view is correct there is needed only the simple confirmation of inspection to prove it. The umbra is the hollow of the vortex ring and is therefore a region of pure absorption such as the spectroscope demands, of low heating capacity crossed by fine spectrum lines as would happen in viewing the gaseous convection currents of the general regions between the photosphere and the nucleus. Even Dawes' dark specks in the nucleus are accounted for by a theory to be mentioned later. The penumbra is the vortex ring itself, at its early development quite free from filaments. These soon appear when the sectional rotation loses velocity, or as the surrounding pressure allows some circulating lines to grow, while others do not, and thus separates the smooth ring into creases or folds which tend more and more to rotate as individual sections or secondary rings. These grow in distinctness and are perceived as filaments with club shaped extremities resembling the perspective effect of a circle viewed nearly across its circumference, the rotation being observed in the spectroscope as upward from the interior and outward radially from the center till the motion disappears under the adjacent compressing photosphere. A fact in detail of almost unquestionable power in demonstration of this theory, is that towards the ripe stage or end of life of the ring a section is seen to emerge into the

hollow of the ring and also to retreat into the photosphere just opposite to it. This is undoubtedly the result of an effort to preserve the law of vortex rings that the product of sectional area into the mean velocity of rotation tends to invariability, and hence that as the velocity diminishes the radius of rotation increases. In fact the whole ring enlarges under this law, but a section shows it clearly because the retreat in both directions is a sign of the motion continuing circular. The life of the ring endures while its force of velocity is being expended, but upon a sufficient retardation and enlargement, breaks up into meaningless wisps, while the photosphere hitherto thrust aside, encroaches in the reverse order of the manner of appearing. Several rings may be ejected successively from the same region of the nucleus and these following each other in close order would produce a combined disturbance in the photosphere, to be afterward regulated by the quick repulsive action between two or three adjoining rings so frequently seen to take place in a fresh group. The crevasses are irregular types where the rings become distorted, the umbra annihilated, while the penumbral appearance seen in contiguous positions indicates a rotation of true filaments which may endure a long while. The region of a group of spots becomes the center of principal activity whereby the internal tension would exhibit itself as flames bursting through the lines of fracture between the ring and the photosphere. In a study of the spots a large margin must be allowed for irregular appearances when dealing with such unstable elements, in the midst of the action of tremendous forces of all kinds, and overlying prominences and faculæ must be carefully distinguished from the true ring. The perplexity which has always attended the preservation of whatever uniformity of structure the spots possess seems to be fully met by regarding them as vortex rings.

This view of the origin of sun-spots would appear to exclude every theory of the interior constitution of the sun other than the one indicated. The question of the distribution of heat is at once raised and the vortex ring fortunately becomes a

rough means of analyzing it. The heat of the surface is the maximum, that of the ring less, and the hollow within the ring relatively a minimum. But the ring is a courier direct from the interior of the nucleus, the umbra is a direct vision of the intra-convectional region and Dawes' black points are the surface of the viscous shell. Therefore unless we are prepared to admit a great change in transmission, we must assume that the envelope formed by condensation at the extremity of the cooling radius has become an area of combustion, and is actually the hottest layer of the sun, the convectional region having half the heat, and the interior of the core four-fifths, while the heat of the shell is as yet undetermined. This statement needs such modification as to allow for the loss of heat in the expansion of the ring. The eighty per cent at the surface may really indicate a temperature within the nucleus even higher than that of the photosphere, since more than one-fifth might be lost when released from the pressure restraining it before ejection. A measurement of the change of heat in the penumbra during the waning of the ring would throw some check upon a solution of this point. It is however clear that the high pressure inside the nucleus assumed by some theories can hardly be allowed, since relief at a fixed tension is afforded by the frequent discharge of the rings. Their pressure therefore indicates the maximum within the core. This argument would tend to revert to the medium temperature theory, say 10,000 degrees Cent., and it must be concluded from all the data that the state of solidification has set in at the surface, although but slightly advanced beyond thick liquefaction, while the gaseous condition of the interior is only approaching the formation of a liquid.

There is, however, one escape from this conclusion of a comparatively cool interior, although it lies in a direction which must at the outset be conceded to be conjectural. The analogy is based upon the laws of vibrations as known in sound and light. Beyond certain limits sound becomes inaudible as possessing periods of frequency too small, or too great; the same is true of light in every particular. In both directions of the

few and the many vibrations in the unit of time, light and sound become super-sensible although it is not presumed that vibrations cease actually at the boundaries imposed by our sensations. The character which distinguishes heat from light no doubt consists more in the form of the wave pulses than in the frequencies ; the like theorem being true of actinic rays. The analogy becomes fascinating to assume that heat vibrations at certain limits become super-sensible. Hence a type of heat may exist within the photosphere which would be practically inoperative, until reduced by cooling to the degree of frequency perceived in the photosphere ; so that if the envelope were suddenly stripped off, other things being unchanged, the nucleus would seem cool and black from its condition of super-heat and super-light. Thus Dawes' black specks may be taken to indicate a comparatively cool or a super-heated surface of the core. A cool interior supplying by its contraction, fuel for the terrific conflagration of the granules is the simplest working hypothesis, and it is hoped that further analysis may justify it, inasmuch as the second theory of super-heat must remain beyond the range of verification.

This mechanical construction of the sun will account for all the phenomena of the spot periodicity, zones, and equatorial acceleration in longitude. First considering the figures of the envelope and the nucleus in a state of rest, it is perceived that the envelope is a true spherical shell of low specific gravity, held in position by the tension of radiation on the inside, and on the outside by the forces of condensation and gravitation, being a state of equilibrium so far as the average shape is concerned. The mutual adjustment continually going on tends to propagate great waves as resultant sinkings and heavings of the surface which are detected in the "réseau photosphérique" of Janssen, or in the change of diameters, measured by several observers, also in the continual interchange of pressure producing prominences both outside, as visible, and inside but hidden. The forces thus arrayed are sufficient to account for the fluctuation of the solar surface, while the general effects of

combustion add the peculiar disturbances known as faculæ in the upper regions. The distinction of photosphere from reversing layer and this from chromosphere and corona, is somewhat arbitrary though of course followed closely by the superposition of the layers under the laws of specific gravity and tension produced by heat.

The nucleus is spherical before rotation, but after it revolves the figure changes strictly according to the laws of solid or viscous bodies, assuming that of an oblate spheroid, while the envelope partaking of the same motion has far less tendency to elongate, since the forces of tension are strong enough to overbalance the centrifugal velocity of the equator by a thrusting of the polar regions. The central oblate spheroid surrounded by a spherical shell contains the data for the solution of our problems.

As a viscous body under rotation assumes this new figure with major and minor axes, there is developed by the pull at the equatorial regions a circle of structural weakness in two latitudes above and below the equator, determined by the velocity attained. This circle of diminished strength on the outer layers is near the intersection of the circle and ellipse of revolution forming the original and ultimate bodies. The strain produced by the contraction of radiation will seek relief by the path of least resistance, so that the vortex rings should be ejected on the average at the two parallels north and south as before indicated. The question of maximum and minimum activity is simply the natural ebb and flow of forces seen in all such operations, and although probably following a general average of recurrence can hardly be constrained within rigid periods in all the details. Thus the eleven year period, with its fluctuations from seven and a half to fifteen years; the shorter time between minimum and maximum, with the longer interval from maximum to minimum; the contracted zones at minimum and the expanded belts of spots at maximum; the non-occurrence of spots at the equator and in higher latitudes, except near the poles where another weak structure should appear; the ejection of rings singly, in pairs,

or in groups, and the observed recurrence of them in the same positions: these and other phenomena are the simple outcome of the mechanical and physical conditions that evidently exist.

The main feature of the figures as a combination, is that the equatorial regions of the nucleus must be nearer the envelope and the polar regions farther from it. The difference in length between the equatorial radius and the polar radius, is the advantage in length of path that a body projected from the equator would have over one projected from the poles, and the intermediate regions pass through a continuous variation of this distance. The shorter the path after projection, the greater is the impact in a ratio depending upon the square of the time, provided the change in acceleration has the same retardation in all cases. The projectile has the tangential velocity of the surface at the point of escape, which diminishes from the equator to the poles, and also the velocity of projection. The resultant path is a parabola, and the body projected at the equator will have a greater relative velocity on striking the envelope than would a body at the poles, supposing the force of normal ejection to be the same. The tangential component of this excess of velocity will tend to accelerate the equatorial regions of the envelope and will impart exclusively a movement in longitude in the direction of rotation. The continuous bombardment of radiation and ejection of the vortex rings will constantly accelerate the equatorial zones in which the spots are observed. Here we have a complete set of data for a study of the inner life of the sun. The sun-spot latitude, which is best obtained at minimum as freed from extraordinary circumstances, will give the circle of latitude drawn at the structural weakness of the ellipsoid, and from it there can be computed the ellipticity of the figure of equal volume with the sphere at rest. This latitude seems to be about 23 degrees north and south. The acceleration of the equatorial zones being about two days in twenty-five, will provide data, for the velocity of motion through a space equal to the difference between major and minor axes, counted from the velocity acquired at the extremity of the equatorial cool-

ing radius, and thence the length of the path between the nucleus and the envelope being combined with the latitude of weakness, ought to produce a good result for the velocity of rotation of the nucleus of the sun, the mass and density of the same, and probably the forces of ejection. It seems useless to encumber this paper with any details of computation considering the paucity of the right kind of observations, therefore the outline only is briefly indicated. It is also to be suggested in this connection that the most minute observations upon the life of the vortex rings be instituted, including the exact length of days they possess, the rate of diminution of velocity to be discovered from the increasing sectional areas, a detailed study of the filaments as a means of measuring the pressure of the surrounding photosphere and hence the general tension of the enveloping shell. Numberless interesting solutions suggest themselves, as, for instance, the slight tendency of the spots to approach the equatorial or the polar edges of the zones from the positions where they were generated, doubtless following a natural law of seeking calmer regions ; or the distinction between sharp crested granules, at the poles or equator, and the rounded granules in the spot zones, which would be due to the conflicting and more tangentially arrayed currents here than in the polar and equatorial portions of the photosphere ; or to the tendency of the faculæ to lag behind the spots, caused by the advance of the ring under the influence of its tangential motion which results in the apparent western side first breaking in, while openings are made in the rear through which the prominences burst forth ; the evident effort of two principal spots of a group to swing the connecting line so as to point east and west and thus follow the direction of the current ; the appearance of the gray and rosy veils under the umbra, which may be shreds of the photosphere torn down and across the opening by the drag of the ring on its side ; the fine dark lines interspersed with bright ones in the umbra, as surmised by Professor Young, due to the general action of the convection currents below, but which may proceed outwards by means of the puff of the motion of the ring ;

and there are doubtless many more not mentioned in this hasty *résumé*.

The usual occurrence of electric terrestrial storms as an accompaniment of the outburst of new spots, which is detected in the disturbance of magnetic currents and auroral displays, yet remains to be noticed. From the 1st of September, 1859, when Carrington saw an electric discharge upon a spot and thus caught the sun in "the very act," this sequence of events has been often described. The vortex ring having an immense superficial area rotates with tremendous velocity in its fresh vitality, and encountering the resistance of the photospheric clouds becomes a machine for generating free frictional electricity upon a vast scale. The particles of condensing metallic vapor, possibly in the shape of incandescent dust as some suppose, become the points of ignition, so that we have a multitude of electric arcs. An analogy is known in the electric flashes accompanying the eruption of volcanoes where the impact of fluids upon suspended particles of dust in the aqueous vapors is a sufficient cause; also in the ejection of steam upon any hard substance. The rotation of the vortex ring thus generating electricity, is a striking confirmation of the theory, and the amount of electricity produced becomes a measure of the force expended in the rotation, so that we have here another path back to the vital power of the sun's nucleus. A final corollary seems to be desired, namely, that this proof of the production of free electricity by one type of phenomena, may be only a fraction of the same thing going on more persistently over the entire photosphere by the friction of the metallic clouds and prominences chafing against each other. In other words, frictional electricity, though resorted to for the explanation of some facts, has not been assigned a position of sufficient influence in extra photospheric phenomena. The sun may well be surrounded by an electric atmosphere extending far beyond our earth, of diminishing intensity as distance from the sun increases, in which there is a tendency not only of repulsion but physical suspension, causing both enormous velocities by its own motion, and enabling

ejections to travel far in the presence of great forces of gravity. The prominences and the faculæ play about the lower and denser regions of it; the corona is a suspension of particles held between the rival powers of gravity and electricity, diminishing in extent during minimum periods of the sun's activity when less electricity is produced, thus enabling gravity to contract the dust and show it more clearly by reflection; the reverse taking place at maximum periods of activity. Possibly the quadrilateral or equatorial structure of the corona is directly related to the region of principal generation of the electricity while the lawlessness of its form is easily comprehended, if not explained. The phenomena of the zodiacal light, the aurora, and the structure of comet's tails are but manifestations of the contention of the laws of gravitation and electric repulsion, acting upon minute particles whose masses are much less affected by the force of gravity than their surfaces are by the force of frictional electricity.

The author will be gratified to feel that some light may have been thrown upon these perplexing problems, though it cannot be hoped that the best analysis has been bestowed upon the numberless details of operation. If a part is correct there opens before us a vast new field of investigation and research.

HINTS ON THE POPULAR STUDY OF ASTRONOMY.

MISS M. E. BYRD.*

For the Messenger.

Everybody looks at the sky, but it is well nigh painful to any student of astronomy to consider how thoughtless and aimless this looking is.

To-night if everyone would begin to look with some definite object in view, and would do some thinking as well as looking, many would be surprised to find how soon there would be a "new heavens" for them.

The first steps toward this end are very easy, and to any

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who care to help themselves or others to a little new pleasure in looking skyward, the following hints are addressed. They are given with no claim to originality, but with the hope that some one may find something suggestive. At first two things only are necessary, a note-book and a motto. For the former anything whatever in the shape of a blank book will answer the purpose. For the motto, nothing better can be found than a saying from a letter of the poet Gray, "Half a word fixed on or near the spot is worth a cart load of recollection." The first thing to be done is simply to go out and look at the sky. For once, turn an earnest, attentive gaze heavenward. Frankly face the question: "Do I have any clear idea of how the sky looks?"

I verily believe that if the spirits of the air some night should roll away the canopy of our heaven, and spread over us some section of the Milky way, with a different configuration of stars, many intelligent people would never know the difference until they were told.

So first and foremost the question is, "How shall I describe the sky to-night?"

The following are suggested as guiding questions that will help to answer the main one. Are there just as many bright stars in one part of the heavens as in another? Toward the south quarter do I find a number of bright stars that characterize that part of the sky? Can I arrange them in some group so as to fix them in mind, that is in a triangle, parallelogram, five sided figure or any easy configuration? Can I in like manner fix other groups toward the north and east? Is there any connection between the bright stars and the Milky way? How is the Milky way placed in the sky? That is, does it lie toward the north or south horizon? Does it intersect the horizon? If so, where on the horizon are these points of intersection? Is the breadth of the Milky way uniform? When these and similar queries are answered a description should be written out on the spot, accompanied by sketches of two or three striking groups of stars copied directly from different parts of the sky. Doubtless this first description will

seem rather crude to the observer himself; and it will not be amiss to spend some time on a number of evenings in correcting and completing it. The sky can be divided into sections by imaginary lines, and several nights devoted to each. In mapping these sections it is well to employ two or three symbols for stars of different degrees of brightness. Directions are readily checked by connecting any three stars in the copy and noting whether the angle thus formed corresponds with the similar angle between the same stars overhead. In measuring distances in the sky have nothing whatever to do with feet and inches. Let the unit be the distance between two familiar stars, and in imagination lay it off a certain number of times from star to star as the sketch progresses.

The star watcher's experience will be very unique, if a score or two of questions do not suggest themselves to his mind before the sky-picture is finished. Whatever the number all should be carefully entered in the note-book. Some of them very likely lie beyond the ken of the most powerful astronomer, and some are not too difficult for the school girl to answer. But before entering upon the consideration of the easiest, it will be a matter of convenience to have names for some of the bright stars and groups of stars. Astronomers are not interested in the ancient grouping of the stars into constellations, and hardly anyone cares to puzzle out the figures of maidens, horses, beasts and birds, but for those who look at the heavens without telescopes it will be pleasant and convenient to have their hosts marshalled within the old boundaries, and under the old familiar names, Orion, Taurus, Gemini, etc. It will be hard to find any star map, old or new, that will not give all the information desired; and anyone who has followed the preceding hints will have no trouble in locating the bright stars of the different groups within their proper limits.

Even thus humbly equipped, the star gazer is ready to find out the answers to an almost unlimited number of simple questions. Very likely on the first night the question comes to mind, How do the stars move? The first step toward the an-

swer is to break up the general question of motion into several specific questions. Are the stars moving away from or toward one another? Are those in the handle of *Ursa Major* coming together, or those in Orion's belt moving apart? Or, on the other hand, is the whole host of heaven moving on in marching order, each one always keeping just so far from every other? If careful sketches of the same groups of stars have already been made on different nights, a close comparison of these should enable the observer to decide whether or not the stars have, with regard to one another, a relative motion that can be detected in a short time by the naked eye. In case the question is decided by maps, made for the purpose, attention should be given to relative rather than absolute distances, and care should be taken not to be biased by any theory.

Having ascertained that for naked-eye vision the stars remain always at fixed distances from one another, it will perhaps require some patient watching and mapping to discover the path and direction taken in their orderly march. Orion is not for this purpose a favorable constellation to observe, nor is the answer that the stars rise in the east, pass across the heavens and set in the west, at all satisfactory. The question naturally following has very probably not been entered in the note-book at all. If the time when a particular star comes into line with two fixed terrestrial marks is noted one evening, and on the following evening the time is observed for the same position of the same star, will the interval be more or less than twenty-four hours? Or in other words, is the sidereal day longer or shorter than the mean solar day? As an illustration of a particular method of answering, the following note-book extract is given:

"Northfield, Minn., Feb. 28, 1887. I selected Beta of *Ursa Major* as my star, and the middle bar of the window sash as the object behind which I waited for the star to disappear. I took my position at the window and noted it carefully. At *7h 15m* P. M. I began watching my star, and at *7h 22m* P. M. it passed behind the window sash." A similar observation

on the following evening enabled the youthful observer to secure quite an accurate answer to the question proposed.

The moon is the most accommodating of heavenly bodies in furnishing a large number of simple questions some of which can be answered in a single clear night. Does the moon move among the stars? In what direction? What is the hourly rate of motion in terms of its own diameter? Two sketches of the moon and a familiar star near it furnish the necessary data. It will be well to have an interval of three or four hours between the sketches, and to take the comparison star near enough to measure its distance conveniently in units of the moon's diameter, *i. e.*, in half degrees. The following are some of the queries that require longer consideration. In any given month is the moon's path in the sky constant? Helping questions are such as these: Does the moon uniformly rise and set at the same points on the horizon? Midway between these points is the zenith distant constant? If there are variations, is the moon moving toward or from the zenith? Are the points of rising and setting moving north or south? It is not at all difficult to fix the point where the moon rises. Choose some convenient place for watching just as the moon begins to appear above the horizon, select two fixed objects in line from the point of view, and so taken that the line prolonged will meet the horizon not very far from the moon, then calculate how many half degrees, *i. e.*, full moons, can lie between the imaginary point of intersection and the moon's center. In the note-book entry, the fixed objects should be sketched or described so as to be easily identified on following nights. After this there comes the still larger question of comparing the paths of the moon in different months. If one can only have patience to collect data throughout the year, some interesting results will be secured. In order to trace the real path of the moon among the stars for any month it is best to make a rough map of the constellations of the zodiac above the horizon, and locate upon it the position of the moon observed as often as possible on different nights and at different hours of the same night. An easy way to make the map is to

lay tissue paper upon the printed map and then mark down such stars as are desired. If such maps are made for different months, the question can be answered whether the moon's path among the stars varies from month to month.

Many of the questions about the moon will apply to the sun and some will not be found too difficult. There is also a whole host of questions about the relative paths of the sun and moon which will naturally suggest themselves.

One can hardly look up at the bright planets without wishing to find out something about them by personal observation.

They are surely moving among the stars.

Are different planets moving with equal rapidity? Is the same planet always moving in the same direction? How is the direction in which a particular planet moves at a given time ascertained? For these and like queries, careful sketching is the key. As a more definite hint for the last, a portion of an entry from a school-boy's note-book is added. Saturn has been carefully located on two sketches including the principal stars in Gemini, the interval being nearly a month. "I compared these two maps, and found on the first map that Saturn was situated about midway between two stars in a small triangle [stars of triangle identified on celestial globe], which is about one half further from Pollux than Castor is. In the second map I find that Saturn has moved away from this first position toward the west. In this map it is seen a trifle above and away from this triangle and away from Pollux. So I find that Saturn is moving westward slowly and the motion is retrograde."

Looking at the sky according to some such method as has been suggested will not be found burdensome or difficult, and it cannot but give pleasure to replace the general vague notion of the spangled blue overhead with some simple but definite knowledge about the sky.

In Mr. Colbert's article in No. 52 entitled, "Motion of the Lunar Apsides," readers will please correct the ninth line from the bottom of page 53 by dropping γ.

EDITORIAL NOTES.

For want of space last month much current matter was deferred, some of which we present this month though it seems late.

By adding sixteen pages to our ordinary size, we are able to give, in this number, a variety of extended articles and a table of news which our readers may deem acceptable dessert.

A Catalogue of 130 Polar Stars.—Some time ago we received the first paper of a series having the title, "A Catalogue of 130 Polar Stars for the epoch of 1875.0 resulting from all the available observations made between 1860 and 1885, and reduced to the system of the publication XIV of the *Astronomischen Gesellschaft* by William A. Rogers and Anna Winlock," of Harvard College Observatory.

In an introductory note, Professor Rogers says that his connection with the paper is limited to the methods of discussion, and to the examination of numerical results obtained. Beyond this that all credit belongs to his assistant, Miss Winlock.

The purpose of the paper is to discuss the modern observations of such polar stars north of $+70°$ as are found in the H. C. Catalogue of 1213 stars. The reduction of stars under 85° north declination involves only the second or third powers of the time for sufficient accuracy, for a limit of fifteen years but for stars near the pole the problem is more difficult. To show how the work was done, the necessary formulæ are stated in order fully, and the tables of constants given, and then a single star, Groombridge 1119, for epoch 1875.0, is taken as an example and its reduction shown in detail. The method of the paper seems excellent and complete, and is a credit to its authors. We shall look with interest for succeeding papers, in which will appear the discussion of other kindred topics named at the close of the one before us.

Star Spectroscope for the Great Equatorial of Lick Observatory.—By kindness of J. E. Keeler of Lick Observatory, we have been furnished blue prints of the drawings designed by

himself, for the new star spectroscope to be used with the 36-inch equatorial. The scale of the two drawings is each ⅓; one presenting the instrument in outline, and the other showing its details. In examining the details of the latter drawing, some points and facts are noticed which are new to us, and all are exceedingly interesting.

The ratio of the aperture to the focal length of the great objective is 1 : 18.7.

The aperture of the telescope object glasses for the spectroscope is 2 inches, and the focal length is 19.5 inches.

Electric illumination is provided for micrometer and vernier readings by a neat design which is new to us though it may not be to others. The instrument is to have a comparison apparatus for metallic and gaseous spectra, a diagonal eye piece for viewing the slit from behind and a reversion attachment. The spectroscope is also to be adapted to general laboratory work.

Some of the interesting matter in Mr. Barnard's article on Celestial Photography which appeared in number 52 was taken from the *Observatory* and the Annual Report of the Paris Observatory. He promptly says that he inadvertently failed to give credit to those publications as he should have done.

Kepler's Correspondence in 1599.—In the introductory note, given last month, to the first letter of this important correspondence, it was stated by whom these three missing letters were found, their respective dates, to whom written, and by whom published in 1886.

That part of the first letter already published is a specimen of the letter-writing of young Kepler at the age of 27. His style is easy and fascinating, often witty and sometimes sensitively delicate, in righting the opinions of his friend on topics belonging to his loved science.

We are not surprised to learn that our readers in different parts of the United States are already anxious to possess these letters and have written for the address of the publisher. It

is probably true that all owners of Kepler's *Opera omnia* would also desire the pamphlet. Such persons should address Victor Dietz in Altenburg (Sachsen-A.), Germany.

The side lights to these letters which appear in the introduction and the supplemental notes are instructive. From them we learn that Herwart's correspondence with Kepler began in 1597, and Kepler was soon involved in it so much that it burdened him, and when so taxed he once said, "There is at the monastery —— Herwartus who keeps asking questions of such a nature that he torments me with great labor, driving me to all those things which Crusinus would have advised."

These questions pertained to the classics, astrology and astronomy. Herwart first touched on the declination of the magnetic needle in 1598 and Kepler became intensely interested in that subject in the following year on account of the "Historia navigationis in Arctum" which had been published the previous year. Kepler refers to that book in a postscript to the first letter. It is noticed with some interest that soon Kepler seeks information from Herwart concerning the magnetic declination in Portugal which the latter gives. Then Kepler advances the hypothesis that, "The magnetic needle points to the pole of the earth which was so by creation;" and later that, "Magnetic force is of the same kind as gravitation." Other points will be mentioned next time.

Haynaldshen Observatorium. — A report containing 178 pages, folio size, with numerous double-page plates prepared by Dr. Carl Braun, S. J., giving account of the work done at the above named observatory, during the last year finds welcome place on our table. While we have not space even in this large number to speak in detail of the many interesting topics presented therein, we must call attention to some, such as, the observation of sun-spots, method, reduction record and mapping of the same. Also the articles on electrical contacts, the passage micrometer, each of which is fully illustrated, and in which there are new and practical ideas that may be considered with profit.

Recent Showers of Meteors.—Between Nov. 17 and Dec. 29, 1886, I saw 375 meteors during 54 hours of observation. In January, 1887, the weather was very cloudy and only 57 meteors were counted during 13 hours of work.

A large number of radiant points have been determined but they apparently represent very feeble streams. The most active display observed during the last few months was from a center at 194°,+67°, between Dec. 18–28, which furnished 17 meteors. The following list of radiants is sent in continuation of that printed in the SIDEREAL MESSENGER for Dec., 1886, p. 309:

Epoch of Shower.	Night of Max.	Radiant Point. R. A.	Dec.	No. of Meteors.	Appearance.
1886.		°	°		
November 17-18	Nov. 17......	53	+ 71	8	Swift, faint.
Nov. 18-Dec. 5	Nov. 30......	190	+ 58	8	Swift, streaks.
November 29-30	Nov. 30......	190	+ 79	6	Rather swift, bright.
November 29-30	Nov. 30......	81	+ 22*	6	Slow.
November 29-30	Nov. 29......	27	+ 71	5	Slow, short and faint.
Nov. 29-Dec. 1	Nov. 29......	64	+ 23	6	Rather slow.
Nov. 30-Dec. 5	Dec. 5......	105	+ 11	5	Swift, bright.
Nov. 30-Dec. 6	Dec. 2......	162	+ 58*	6	Very swift, streaks.
December 15-29	Dec. 20......	47	+ 65	5	Very slow, trained. Faint.
December 15-25	Dec. 18......	80	+ 24*	6	Slow.
December 18-28	Dec. 22......	194	+ 67	17	Swift, streaks.
December 18-29	Dec. 18......	134	+ 8	6	Very swift, thin streaks.
December 20-29	Dec. 25......	98	+ 31	5	Very slow, trained.
December 21-28	Dec. 28......	194	+ 32	7	Very swift, streaks.
December 22-24	Dec. 24......	129	+ 19	5	Rather swift.
December 22-28	Dec. 24......	218	+ 36	8	Very swift, bright streaks
December 22-28	Dec. 28......	115	+ 32*	7	Slow.
December 24-28	Dec. 24......	184	+ 39	6	Very swift, streaks.
December 24-31	Dec. 24......	77	+ 32	5	Slow.
December 28-29	Dec. 29......	231	+ 52	5	Rather swift, long.
1887.					
January 25	Jan 25......	180	+ 24	5	Swift.

* Seen also in December, 1885. See SIDEREAL MESSENGER, Feb., 1886, page 61.

I recorded nothing of the Leonids, Andromedes or Geminids in 1886, observations being hindered either by moonlight or overcast skies at the special epochs of their return.

Bristol, England, Feb. 27, 1887. W. F. DENNING.

A valued friend of the MESSENGER calls attention to the fact that the photograph of the Nebula of *Orion* by Dr. Draper was made with his 11-inch photographic refractor and not with an 18-inch reflector as stated in Mr. Barnard's article in our February number. It is also true that the aperture of Dr. Draper's reflector was 28 inches instead of 18.

Comet d, 1887 (Barnard, Feb. 16).—February 17, Mr. Barnard writes, "A new comet was discovered here on the night of February 16, at about 10*h* 30*m*. It was very faint and moving with astonishing rapidity to the northwest, 14*m* 45*s* west, and 5° 17′ north daily.

Ring micrometer comparisons were made with a 7th magnitude star near which the comet passed. The star has not yet been identified. The following is the instrumental position of the comet at 10*h* 58*m*, Nashville M. T.:

$$\text{R. A.} = 8h\ 4m\ 9s.$$
$$\text{Decl.} = -16°\ 15.5'$$

Vanderbilt Univ. Obs'y. E. E. BARNARD.

Orbit of Comet d 1887 (Barnard).—From my own observations of Feb. 16, 22, 28, I have computed the following orbit of the above comet:

$$T = 1887 \text{ March } 26.5258$$

$$\left.\begin{aligned} \omega &= 34°\ 33.4' \\ \Omega &= 134°\ 47.8' \\ i &= 139°\ 46.7' \end{aligned}\right\} 1887.0$$

$$\log q = 0.002449$$

E. E. BARNARD.

Vanderbilt Observatory, Nashville, Tenn., March 16, 1887.

Orbit of Comet 1887 d (Barnard, Feb. 16).—From observations of Feb. 22, 25 and 28, I have computed the following orbit of Comet 1887 *d*.

ELEMENTS.

$$T = 1887.\ \text{Mar. } 28.5188 \text{ Gr. M. T.}$$

$$\left.\begin{aligned} \pi - \Omega &= 36°\ 39'\ 34'' \\ \Omega &= 135\ \ 26\ \ 22 \\ i &= 139\ \ 45\ \ 10 \end{aligned}\right\} \text{Ap. Eq.}$$

$$\log q = 0.00250$$

Middle Place $(C-O)$

$$\Delta\lambda \cos\beta = -9''$$
$$\Delta\beta = +2''$$

O. C. WENDELL.

Harvard College Observatory, Mar. 10, 1887.

Occultations of Stars by Dark Limb of the Moon.—At the Davidson Observatory, San Francisco, Cala. Clark equatorial, 6.4 inches.

Date, 1887.	Observer.	Power.	Star.	Magn.	Local Sider'l Time.	Remarks.
					h m s	
Jan. 28.	G. F. D.	90	(? Stone 139)..	7	5 46 41.6	Obsn. good. (*a*)
Feb. 2..	G. D...	90	70 Tauri	6	5 49 21.5	Obsn. good, but star faint; obj. partly covered.
" 2..	G. D...	90	Arg. 15: 630..	8 7	7 50 23.5	Disappearance sharp and sudden.
" 2..	G. D...	90	θ' Tauri	4	7 50 45.5	Disappearance sharp and sudden.
" 2..	G. D...	90	75 Tauri	6	7 51 23.4	Disappearance sharp and sudden.
" 2..	G. D...	90	Arg. 15: 633..	6.5	7 54 30.2	Disappearance sharp and sudden.
" 2..	G. D...	90	Arg. 15: 635..	8.5	8 31 21.7	Disappearance sharp and sudden.
" 2..	G. D...	90	B. A. C. 1391.	5	8 46 09.6	Disappearance sharp and sudden.
" 2..	G. D...	90	B. A. C. 1394.	7	8 53 38.3	Disappearance sharp and sudden.

(*a*) Identity of this star somewhat doubtful. Transit observations for time, for this and the observations of Feb. 2d, by G. D.

Observers: G. F. D. = G. Fountleroy Davidson.
G. D. = George Davidson.

Geographical position of Observatory:
Latitude = 37° 47′ 24.75″ N.
Longitude = 122° 25′ 40.54″ W.

Public Parks and Scientific Institutions.—We notice that there is a bill before the Legislature of Illinois to empower the corporate authorities of public parks to set apart so much, or such parts of the public grounds, as may be desirable or necessary for Botanical Gardens, Astronomical Observatories, or other Scientific Associations, and to give these societies or associations exclusive control of the sites so designated during their maintenance or continuance. The bill further provides that the corporate authorities before named shall have power to make, from time to time, such appropriations for establishing and maintaining the same as they may deem necessary for the advancement of scientific knowledge, or the promotion of the general welfare.

In the main this seems to be a wise provision, although certainly a novel one in this country. Such a plan would evidently awaken interest in scientific pursuits in the public mind and doubtless lead to useful support which ought to come from the public generally on account of corresponding benefit.

The drawback at once suggested is, that interruption which will seriously impair quiet and continuity in the pursuit of certain classes of scientific work. This and like objections can, however, be overcome in a considerable degree by wise planning. We sincerely hope the experiment will be tried, for no one can doubt the popular educating influence of such a plan if managed wisely.

Occultations of Stars in the "Hyades" at dark limb of the moon, Feb. 2, 1887: observed at the Chabot Observatory, Oakland, Cala., Supt. F. M. Campbell, Director.

Star.	Local Sidereal Time.			Remarks.
70 Tauri	5*h*	50*m*	14.8*s*	Apparently not instantaneous.
θ' Tauri	7	51	27.1	Good, instantaneous.
Arg. + 15:633	7	55	16.2	Good, instantaneous.
Arg. + 15:635	8	32	03.6	Good, instantaneous.
B. A. C. 1391.........	8	46	50.7	Good, instantaneous.

θ' Tauri was observed to emerge at 8*h* 36*m* 54.9*s* ± 05.0*s*, a weak observation, at bright border.

These were all observed with the 8-inch Clark equatorial, by Mr. Chas. B. Hill.

The geographical position of the Observatory is

Latitude, 37° 48′ 05″ N.
Longitude, 8*h* 09*m* 06.3*s* W.

The Boyden Fund of Harvard Observatory.—By will of U. A. Boyden $230,000 was left in trust to Harvard College for the purpose of astronomical research, "at such an elevation as to be free, so far as practicable, from the impediments to accurate observations which occur in the observatories now existing, owing to atmospheric influences." The first step in carrying out this will is to obtain knowledge of suitable places of sufficient altitude to secure the kind of observations sought. To this end Professor Pickering has issued a circular asking for detailed information on the following points:

1. Latitude and longitude. Distance and direction from some town, or other well-known point. Height, and how determined.

2. Peak, pass, or table land. Character of surface: ledge, broken rock, gravel, or covered with trees, shrubs, or grass. Prevalence of snow in summer, and period during which the depth of snow in winter might obstruct the paths of access, or occasion other inconvenience or damage. Proximity of wood for fuel, and of water.

3. Means of access, distance from and height above the nearest railroad station, wagon road, bridle-path, or footpath. Time of ascent and descent. Nearest post-office and telegraph station, and their distances from the proposed station. Nearest point of road kept open in winter.

4. Observation of the rainfall at different seasons of the year. Proportion of the sky covered with clouds at different hours and seasons. These observations are desired at sunset, sunrise, and late in the evening. Such observations may also be made of a distant mountain peak, confining the evening observations to moonlight nights. Observations of the barometer and thermometer are also desired. Information is wanted regarding the prevalence of very high winds; the presence of dust, haze, or the smoke from forest fires, rendering distant points invisible; and all other meteorological phenomena affecting the value of the station for astronomical purposes. If there is a rainy or cloudy season, its duration; also the regular recurrence of clouds, thunder-storms, or wind, at any given hour of the day.

5. Sketches or photographs of the proposed location, and of points on the road; also of the view.

We are sure that our genial friend J. A. Brashear, of Allegheny, Pa., will not object to our telling the readers of the MESSENGER what is now going on in his new shops in the interest of astronomy. He has the order for the great spectroscope for the 36-inch equatorial of Lick Observatory, elsewhere particularly spoken of; the mounting of a 6½ inch glass for Francis G. du Pont, of Wilmington, Delaware; a spectroscope for the University of California; one for another college; one for R. R. Beard, Pella, Iowa; a concave grating spectroscope of large size for the University of Madison; one for Geo. E. Hale, of Chicago; and other astronomical instruments for some prominent American astronomers.

Mr. Brashear's work is receiving very favorable notice in Europe as well as at home, another mark of respect for American industry and skill.

Brightness and Masses of Binary Stars.—In *Observatory* No. 120, W. H. S. Monck has an interesting paper on the relation of the brightness and masses of binary stars, depending mainly on the assumption that the mass of the smaller star of each pair is very small compared with that of the larger. The relation is independent of distance or parallax, but does use constants of photometry easily obtained by observation. Readers of the MESSENGER who may refer to the *Observatory* for the discussion of this method will please notice that the factor, in the final formula, $P \div P'$ should be affected with the fractional exponent ¾.

Mr. Common's Photograph of Orion.—By our request, Mr. A. A. Common of England has favored us with a copy of his photograph of Orion which astronomers in America have recently and justly spoken of with very favorable comment. This picture was taken by the use of Mr. Common's 3-foot reflecting telescope with particular details of exposure of which we are not informed. The results obtained are excellent.

In January last Mr. Common was himself at work on a larger telescope with which he expects to obtain even better results.

U. S. NAVAL OBSERVATORY.

The Great Equatorial.—Observations of double stars will be continued. Observations of previous years will be discussed if time and force will permit.

Continuation of measurements of the fainter stars in the Pleiades. Completion of these observations if possible.

Observations of the conjunction of the five inner satellites of Saturn with the minor axis of the ring, and the angles of position and the distances of the faint satellite Hyperion.

Reduction and discussion of the observations of former years as time and force will permit.

The Small Equatorial.—Observations of comets whenever possible.

Observations of stars that need to be identified for the pre-

paration of the third edition of Yarnall's catalogue, now in progress.

Observations of stars and asteroids for identification for the transit circle, and of such asteroids as cannot be observed with that instrument.

Observations of occultations of stars by the moon whenever practicable.

The Transit Circle.—Completion of the observations of miscellaneous stars for the proposed Transit Circle catalogue; concurrently with these, observations of the sun, moon and planets.

After the completion of the above observations (which, it is hoped, will be accomplished by the 1st of March), the instrument will be dismounted for repairs, and will thereafter be used in observations of—

The sun daily.

The moon throughout the whole lunation.

The planets, major and minor.

Stars of the American Ephemeris, required for the determination of instrumental and clock corrections.

Miscellaneous stars, as may be deemed advisable.

The observations of preceding years will be reduced as rapidly as possible.

The Transit Instrument.—Observations for the correction of the standard mean time clock daily.

The Repsold Circle (at Annapolis).—Observations of the 303 southern stars.

The 59 refraction stars of the Leiden Observatory.

Auxiliary stars of the Berlin Jahrbuch.

CAPT. R. L. PHYTHIAN, U. S. N. SUPT.

BOOK NOTICES.

The Elements of Geometry, by Webster Wells, S. B., Associate Professor of Mathematics in the Massachusetts Institute of Technology. Messrs. Leach, Shewell & Sanborn, Publishers, Boston and New York.

This book covers the usual ground of Plane and Solid Ge-

ometry, and in matter and arrangement its author lays no claim to originality. The course in Plane Geometry is divided into five books, followed by an appendix on symmetrical figures, and a few interesting theorems on maxima and minima of plane figures.

The remainder of the book is devoted to Solid Geometry, and is divided into four parts, the first treating of lines, planes and angles in space; 2, polyedrons; 3, cylinder, cone and sphere; 4, the measurement of the cylinder, cone and sphere. The considerable number of brief and simple exercises given with the various topics is a helpful feature for the class-room as well as the private student. The publishers have done their part well and very neatly.

A Treatise on Algebra, by Professors Oliver, Wait and Jones, of Cornell University, Ithaca, N. Y. Dudley F. Finch, 1887.

In working out the plan of this new book the authors have widely departed from the ordinary course of treating the subject-matter of Algebra. They have aimed to prepare a treatise in such a way as to assume no previous knowledge of the branch, by laying down first the primary definitions and axioms and building on these to develop the elementary principles in logical order, particular attention being given both to the matter and the form of its presentation. The new things that frequently meet the eye of the student of some experience will be somewhat surprising, and some may stop reading to ask if these enthusiastic Cornell men are not getting a little unorthodox in their notions touching the good old creeds of the fathers in Mathematics, for there seems here to be great liberty of conscience that may unsettle time-honored requisites for college standing in Algebra if their standard should obtain general favor.

The first twenty pages which treat of primary definitions and signs are largely given to the explanation and illustration of the mathematical language of the book, including the use of the ordinary signs and many others new, as subscript numbers and superior numbers, letters, accents and signs, Greek

letters and fractional forms. On page 2, we notice that $x \div y$ is to be read "x over y." Is not that reading both inaccurate and inelegant? Carleton students are taught so.

On page 16, under the first group of exercises for expression a, with exponent b, in parenthesis, with exponent c is to be read "the cth power" of a with exponent b. Suppose c is fractional or itself a negative quantity, would the direction be the best reading possible? When the exponent is a letter, variable or constant, is it not more accurate to call the superior an exponent? No fractional or negative superior can be called, strictly speaking, a power or a root unless it be a fraction with unity for its numerator. The general plan of all this introductory work is very excellent, and the thoroughness and completeness of the system will pay for the extra effort to get the increased vocabulary. The student will be led to think and express his thought more commonly in mathematical terms, and so easily acquire the peculiar habit of conciseness and directness that the study ought to furnish.

Further on, some new topics and some unusually treated are found; as, Absolute and Relative Error; Continued Fractions, Limits, Infinitesimals, Incommensurables, Derivitives and Imaginaries. The subject of Infinitesimals finds suitable place in this Algebra as it ought to in every one, and the Imaginary is dealt with after the graphic method, which is certainly interesting if its language does sound like that of Quaterinons. This is an excellent book of reference for teachers, but too full for ordinary classes. It is best suited to students who have some knowledge of Algebra and Geometry before undertaking it.

A Treatise on Trigonometry, by Professors Oliver, Wait and Jones, of Cornell University. Second Revised Edition. New York: John Wiley & Sons, 1884.

Though not a new book, it is a pleasure to look over this Trigonometry, and call attention of the readers of the MESSENGER to it as presenting the ordinary themes of Plane and Spherical Trigonometry in a very judicious and scholarly way. The copy before us is not provided with the ordinary tables. The publishers always do their part handsomely.